ATTACHMENT 2

RS FACT SHEET

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Document Title: PRELIMINARY DRAFT NEW RECOMMENDATION, CRITERIA FOR SHARING BETWEEN THE MOBILE-SATELLITE (SPACE - TO - EARTH) NON-GSO SYSTEMS AND THE FIXED SERVICE IN THE 2483.5 - 2500 MHZ FREQUENCY BAND

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Purpose/Objective:

To establish Recommended values of power flux-density (pfd) to serve as the threshold to protect fixed service systems. These values are applicable to the emissions of non-GSO MSS systems operating in the 2483.5-2400 MHz band. Coordination with affected administrations will be initiated when the pfd produced by non-GSO systems is in excess of the recommended values.

Abstract:

Values of pfd to protect analog and digital radio-relay systems from interference in excess of permissible values as a result of emissions from LEO D type MSS systems have been studied. The characteristics of the radio-relay systems considered were derived from the guidance given in Doc. 2-2/TEMP/8(Rev.1). Values of pfd from -147 dB(W/m^2 4 kHz) for elevation angles of 5 degrees or less, linearly escalating to -134 dB(W/m^2 4 kHz) for elevation angles of 25 degrees and greater were found to be sufficient to protect analog radio-relay systems. Point-to-point and point-to-multipoint radio-relay systems using digital techniques were found to require values of pfd some 12 dB more stringent than analog systems require.

Based on the results of the study, the preliminary draft new recommendation recommends that the threshold pfd values for coordination be based on protecting analog radio-relay systems and that digital systems be designed to operate compatibly within these limits. Two Annexes are included that summarize the study and justify the proposed pfd values.

UNITED STATES OF AMERICA

PRELIMINARY DRAFT NEW RECOMMENDATION

CRITERIA FOR SHARING BETWEEN THE MOBILE-SATELLITE (SPACE - TO - EARTH) NON-GSO SYSTEMS AND THE FIXED SERVICE IN THE 2483.5 - 2500 MHZ FREQUENCY BAND
(Question 202/2)

CONSIDERING

a)   that WARC-92 allocated the 2483.5-2500 MHz band for space-to-Earth transmissions of non-GSO mobile satellite systems on a co-primary basis with fixed services operating in that band;

b)   that WARC-92 invited Task Group 2-2 of the CCIR to study criteria for sharing and coordination between systems in the mobile satellite service and the fixed and mobile services, and make appropriate recommendations;

c)   that the 2483.5-2500 MHz band paired with the 1610-1626.5 MHz band (for Earth-to-space transmissions) has been identified for implementation by several non-GSO MSS systems that are currently seeking regulatory approvals;

d)   that RR No. 2566 identifies power-flux density (PFD) levels as a coordination trigger for protection of receiving stations in the fixed service from transmitting stations in the mobile satellite service, and provides for a mechanism for coordination when the trigger values are exceeded;

e)   that in order to meet basic quality of service with portable hand-held devices, the mobile satellite systems may need to operate at PFD levels in excess of the levels specified in RR No. 2566;

f)   that a draft new Recommendation ITU-R [Document 9/178] provides the methodology for calculating interference levels from non-GSO/MSS constellation downlinks into fixed service receivers;

g)   that Task Group 2-2 in Document 2-2/TEMP/8 (Rev. 1), identified three types of fixed service systems (analog point-to-point, digital point-to-point, digital point-to-multipoint including local access systems) that need to be considered for sharing analyses in the 1-3 GHz band;

h)   that the analyses performed with the methodology outlined in the draft new Recommendation ITU-R [Doc. 9/178] indicate that it is feasible to share the spectrum with analog radio-relay systems and meet the requirements of ITU-R Rec. 357 even when operating at higher PFD values than utilized for coordination triggers in RR No. 2566 (Annex 1);

i)   that analog radio systems predominate in the 2483.5-2500 MHz band;

j)   that sharing with digital point-to-point and point-to-multipoint radio-relay systems require non-GSO/MSS downlink PFD values that are significantly lower than the values required for sharing with analog radio-relay systems (Annex 2), and will inhibit the use of portable hand-held terminals in the MSS service;

RECOMMENDS

1)   that the methodology outlined in the draft new Recommendation ITU-R [Doc.9/178] should be utilized along with Recommendation ITU-R F.357, to determine the threshold values of PFD for the non-GSO/MSS downlink transmissions;

2)   that protection of analog radio-relay receivers from non-GSO/MSS system downlink transmissions should be used as a basis for developing appropriate threshold values of PFD;

3)   that, based on the analysis given in Annex 1, the following PFD values should be used as coordination threshold values between non-GSO/MSS downlinks and fixed services in the 2483.5-2500 MHz frequency band;

-147 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;

-147 + 0.65(δ-5) dB(W/m^2) in any 4 kHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane;

-134 dB(W/m^2) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane;

4)   that digital point-to-point radio-relay systems implemented in the 2483.5-2500 MHz band should be designed and operated to be compatible with the PFD values given in Recommends 3;

5)   that higher PFD values than the threshold values given in Recommends 3 can be employed by non-GSO/MSS downlinks using the coordination procedures outlined in Recommendation ITU-R-[xxx].

Annex 1

PFD Levels From Non-GSO MSS Systems To

Protect Analog Line-of-Sight Radio-Relay Systems

1. Introduction

The purpose of this Annex is to present the results of an analysis to determine the pfd levels necessary to protect a 2500 km hypothetical reference circuit (HRC) of an analog radio-relay system from interference from the emissions of a LEO D type non-GSO mobile-satellite system. The methodology of Draft New Recommendation ITU-R [Doc. 9/178] was used for the analysis. The statistical interference to radio-relay systems is determined for routes centered at 15 degrees, 40 degrees and 60 degrees latitude, and with trendlines that range from 10 degrees to 170 degrees in 20 degree steps.

The following sections describe the approach used for the study, the technical characteristics of the analog radio-relay system, the technical characteristics of the LEO D system, a summary of the results of the analyses and conclusions regarding pfd levels to protect analog radio-relay systems.

2. Analysis

2.1. Approach.

The methodology for the analysis is set forth in Draft New Recommendation ITU-R [Doc. 9/178]. It is assumed that there are 51 analog stations on a route centered at a given latitude. The routes span a distance of 2500 km with stations spaced exactly 50 km apart. The azimuth angle for each station is specified by a given trendline angle and a variable angle that is uniformly distributed between ±12.5 degrees. The analysis considers trendline angles that vary between 10 degrees and 170 degrees in 20 degree steps. Each station is assumed to use a high gain antenna pointed at the next station at an elevation angle of 0 degrees.

The analysis is performed using a simulation program. The program assumes that the satellites move in circular orbits perturbed only by the oblateness of the earth. The program calculates the satellite orbital positions and visibility to each station in 8 second increments for one repeat cycle, which is 47.5 hours. At each time sample, the program calculates the aggregate interference noise power received at all stations on the route from all visible satellites as

$$I = \sum_{i=1}^{N} \sum_{j=1}^{51} \rho(\delta_{ij}) A_{iso} G(\theta_{ij})$$

where

    i = 1 of N visible satellites

    j = 1 of 51 stations on a route

    $\rho(\delta_{ij})$=the power flux-density received at station j from the ith satellite

δ_{ij}= the elevation angle from station j to the ith satellite

A_{iso}= area of an isotropic antenna = $\lambda^2/4\pi$

$G(\theta_{ij})$= j^{th} station's antenna gain in the direction of the ith satellite

θ_{ij}= angle between the jth station's antenna pointing vector and the range vector from the jth station and the ith satellite.

The pfd incident on the station's receiving antenna as a function of the elevation angle was assumed to be of the form

$$\rho(\delta) = \rho(5) \qquad\qquad 0 \le \delta < 5 \deg \qquad\qquad (1a)$$

$$\rho(\delta) = \frac{\rho(25) - \rho(5)}{20}(\delta - 5) + \rho(5) \qquad 5 \deg \le \delta < 25 \deg \qquad (1b)$$

$$\rho(\delta) = \rho(25) \qquad\qquad 25 \deg \le \delta \le 90 \deg \qquad (1c)$$

where

δ= elevation angle (degrees)

ρ= pfd (dBW/(m²)) in a reference bandwidth

$\rho(5)$= pfd value at 5 degrees elevation and below

$\rho(25)$= pfd value at 25 degrees elevation and above

The station antenna gain conforms to the antenna pattern having averaged sidelobe levels as defined in Note 6 of Recommendation ITU-R F.699-1 as revised by the Study Group 9 Plenary meeting in March 1994. The station antenna gain is defined as a function of the off-boresight angle θ is

$$G(\theta) = G_{max} - 2.5 \times 10^{-3}\left(\frac{D}{\lambda}\theta\right)^2 \qquad 0 \le \theta < \theta_m$$

$$G(\theta) = 2 + 15 \log\left(\frac{D}{\lambda}\right) \qquad \theta_m \le \theta < 75.86\frac{\lambda}{D}$$

$$G(\theta) = 49 - 10 \log\left(\frac{D}{\lambda}\right) - 25 \log(\theta) \qquad 75.86\frac{\lambda}{D} \le \theta < 48^o$$

$$G(\theta) = 7 - 10 \log\left(\frac{D}{\lambda}\right) \qquad 48^o \le \theta$$

where

λ = carrier wavelength

D = antenna diameter

G_{max} = antenna gain at boresight

$\theta_m = \left(\frac{20\lambda}{D}\right)\sqrt{G_{max} - G_1}$

G_1=gain of the first sidelobe=$2 + 15\log\left(\frac{D}{\lambda}\right)$

D/λ is estimated by $20\log\left(\frac{D}{\lambda}\right) = G_{max} - 7.7$

The program calculates the interference statistics based on the aggregate interference noise power calculated at each sample point. The interference statistics show the probability that the aggregate received interference noise power exceeds a given interference level. The interference level is then mapped to the total interference noise power in a 4 kHz telephony channel by

$$N_{ch} = \frac{N_T}{kTB}I$$

where

N_T = thermal noise power introduced in a 4 kHz telephony channel at a station = 25 picowatts psophometrically weighted at a point of zero relative level (pW0p)

k = Boltzmann's constant

T = station receiving system noise temperature

B = reference BW = 4 kHz

I = aggregate received interference noise power in the reference BW

2.2. Non-GSO LEO D satellite system parameters.

The following parameters were assumed for the non-GSO LEO D satellite system:
- 48 satellites that all transmit continuously.
- The 48 satellites are located in 8 orbital planes, which are separated by 45 degrees.
- The difference between the mean anomaly of satellites in adjacent orbit planes is 7.5 degrees.
- The six satellites in each plane are separated by 60 degrees.
- The orbital altitude is 1414 kilometers (km).
- The orbit planes are inclined 52 degrees with respect to the equatorial plane.

2.3. PFD levels

As shown previously in equation (1), the pfd levels affecting the analog fixed service networks were assumed to be a minimum value for elevation angles less than 5 degrees, a maximum value for elevation angles greater than 25 degrees, and to linearly increase between the minimum and the maximum levels for elevation angles between 5 and 25 degrees. The pfd levels used in the analysis were
- Minimum value of -147 dBW/m^2 in a 4 kHz reference bandwidth escalating to a maximum value of -136 dBW/m^2 in a 4 kHz reference bandwidth; and,
- Minimum value of -146 dBW/m^2 in a 4 kHz reference bandwidth escalating to a maximum value of -136 dBW/m^2 in a 4 kHz reference bandwidth.

2.4. Analog fixed service network parameters.

The analog fixed service network parameters are:
- 51 analog stations located along a 2500 km route that is centered at 15 degrees, 40 degrees, or 60 degrees latitude.
- Centered at each latitude are 9 routes that have trendline angles that vary between 10 degrees and 170 degrees in 20 degree steps.
- The antenna boresight gain is 33 dBi as suggested in Annex 1 to Doc. 2-2/TEMP/8(Rev.1).
- Each analog station has a noise figure of 8 dB, a feed line loss of 3 dB and an antenna temperature of 290 K, also as suggested in Annex 1 to Doc. 2-2/TEMP/8(Rev.1).

3.   Results.

Interference to analog fixed service networks located at 15 degrees, 40 degrees and 60 degrees latitude for two cases of pfd values are shown in Figures 1 through 6. Figures 1 through 3 relate to pfd values ranging from -146 dB(W/m^2 4 kHz) to -136 dB(W/m^2 4 kHz), whereas, Figures 4 through 6 relate to pfd values ranging from -147 dB(W/m^2 4 kHz) to -134 dB(W/m^2 4 kHz). These figures also show the recommended interference limit provided in Recommendation ITU-R F.357-3, i.e., 1000 pW0p for 20% of the time (probability of 0.20) increasing to 50000 pW0p for 0.01% of the time (probability of 0.0001) in a 4 kHz telephony channel. Figures 1 and 4 show that all analog radio-relay routes centered at 15 degrees latitude will experience interference at levels less than those in Recommendation ITU-R F.357-3.

For analog radio-relay routes centered at a 40 degree latitude, the interference for small percentages of time is well within the limits of Recommendation ITU-R F.357-3 as shown in Figures 2 and 5. For 20% of the time, the figures show that only one or two of the trendlines will experience interference marginally in excess of the recommended value. It is suggested that the number of affected routes may be less than 10% of the routes centered at 40 degree latitude.

Figures 3 and 6 show the interference to analog radio-relay routes centered at 60 degree latitude. The figures show that the interference limits contained in Recommendation ITU-R F.357-3 will be met for all but one trendline. This particular trendline corresponds to the azimuth angle for which the radio-relay antennas intercept the orbital sphere at a latitude equal to the inclination of the orbital plane.

4.   Conclusions.

From the results presented here, it may be concluded that interference to almost all 2500 km analog radio-relay routes will be within values contained in Recommendation ITU-R F.357-3 for pfd levels ranging from -146 dB(W/m^2 4 kHz) for elevation angles less than 5 degrees linearly increasing to -136 dB(W/m^2 4 kHz) for elevation angles equal to and greater than 25 degrees. This conclusion also applies to pfd values ranging from -147 dB(W/m^2 4 kHz) at elevation angles less than 5 degrees linearly increasing to -134 dB(W/m^2 4 kHz) for elevation angles equal to and greater than 25 degrees.
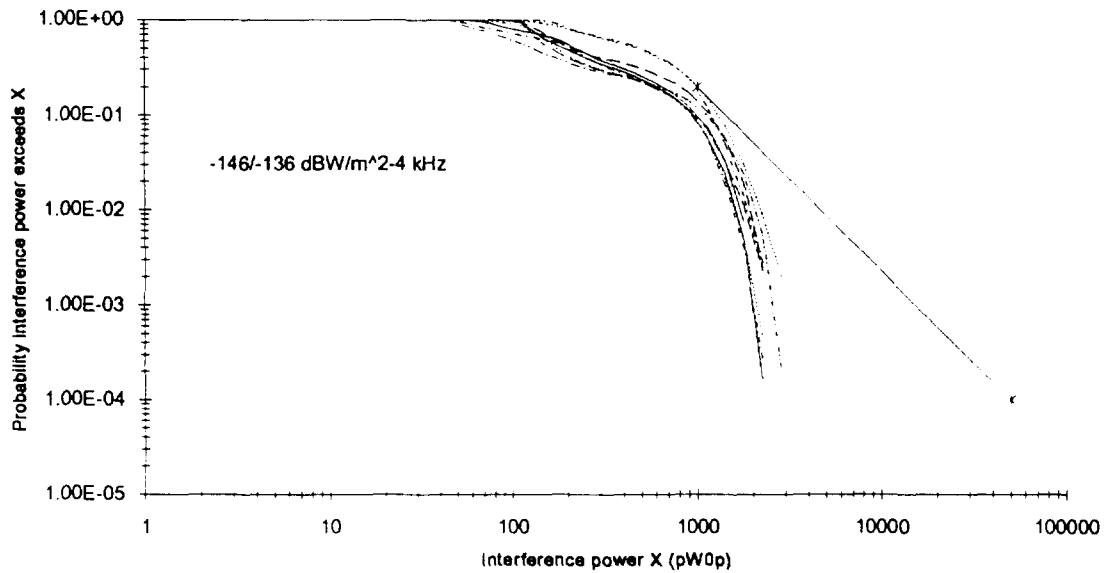
Figure 1 - Statistical interference to 2500 km analog line-of-sight radio-relay routes centered at 15 degrees latitude: G_0=33 dBi; 10 dB pfd escalation factor.
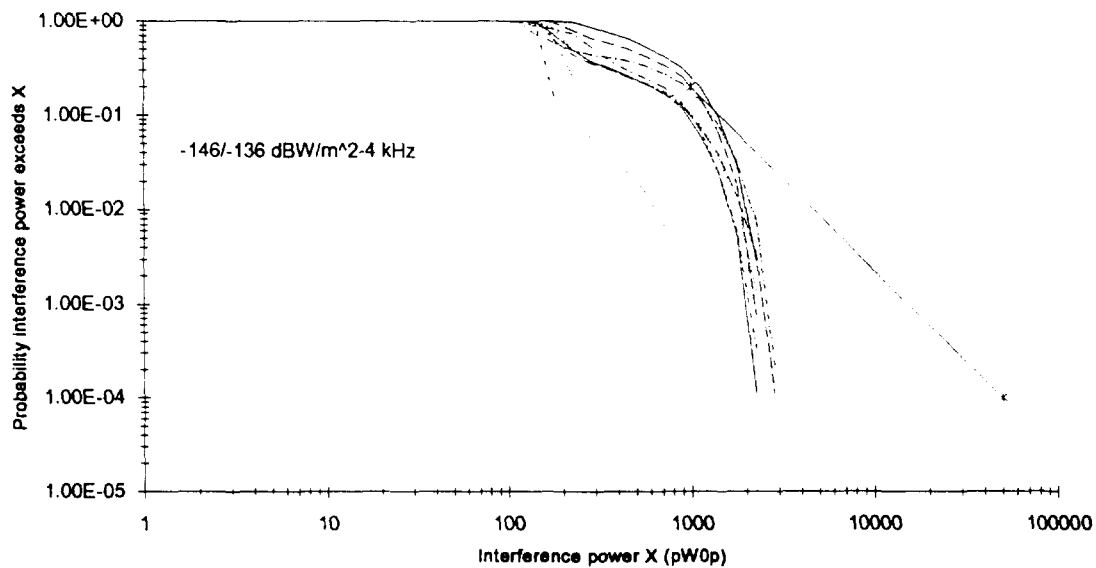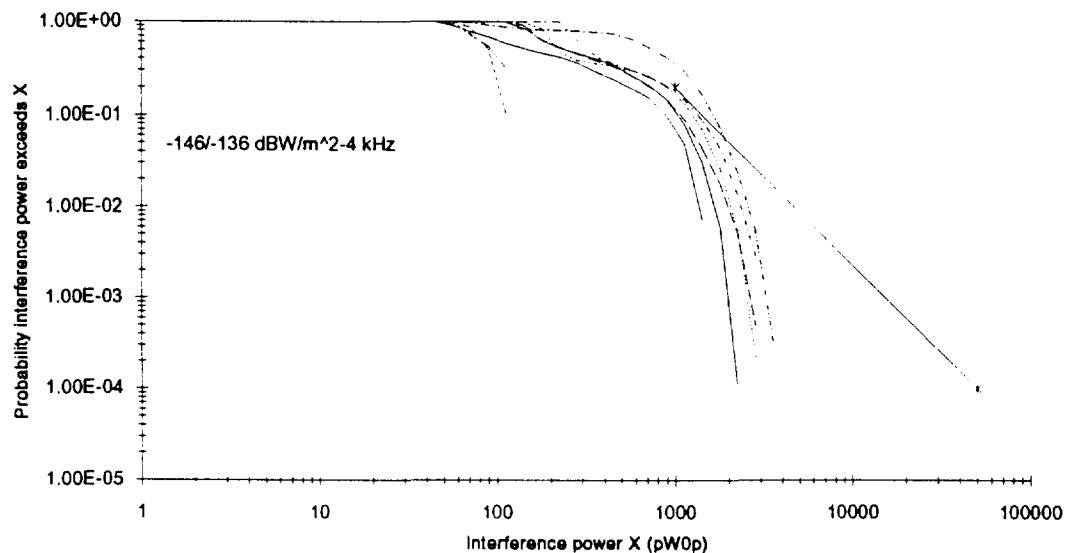

Figure 2 - Statistical interference to 2500 km analog line-of-sight radio-relay routes centered at 40 degrees latitude: G_0=33 dBi; 10 dB pfd escalation factor.
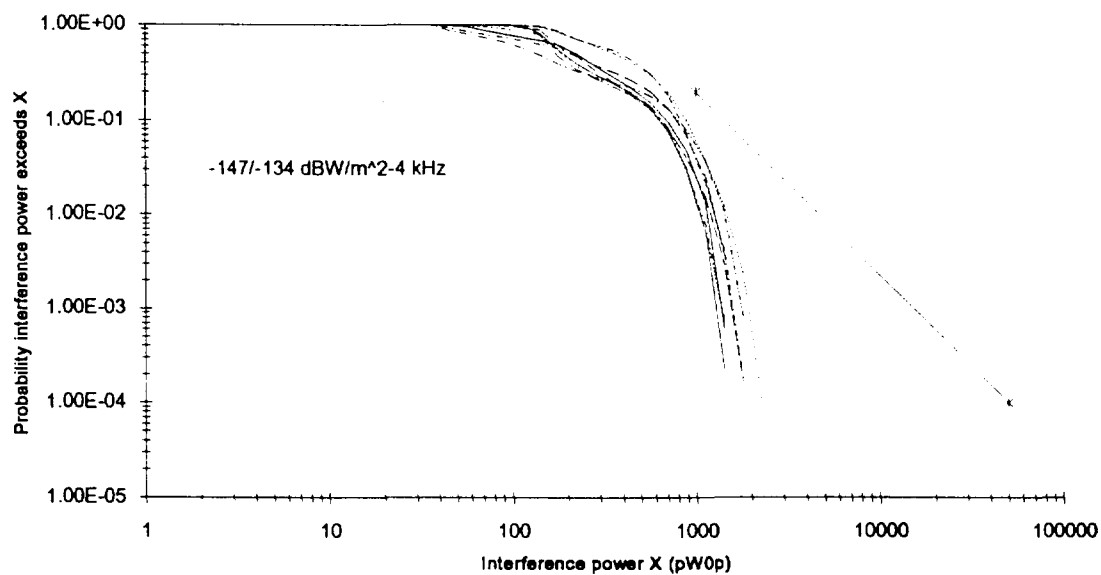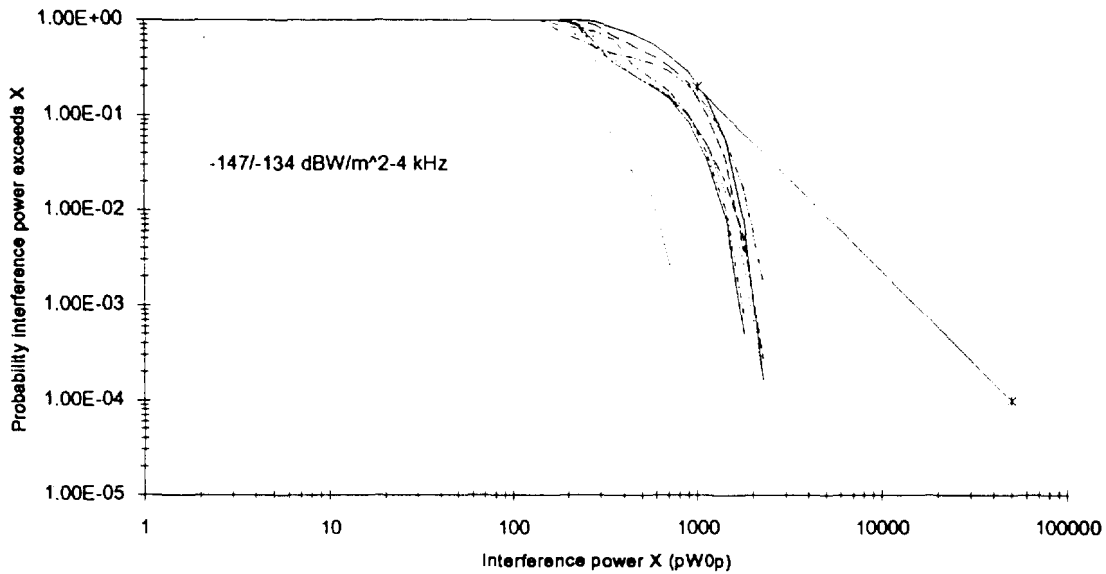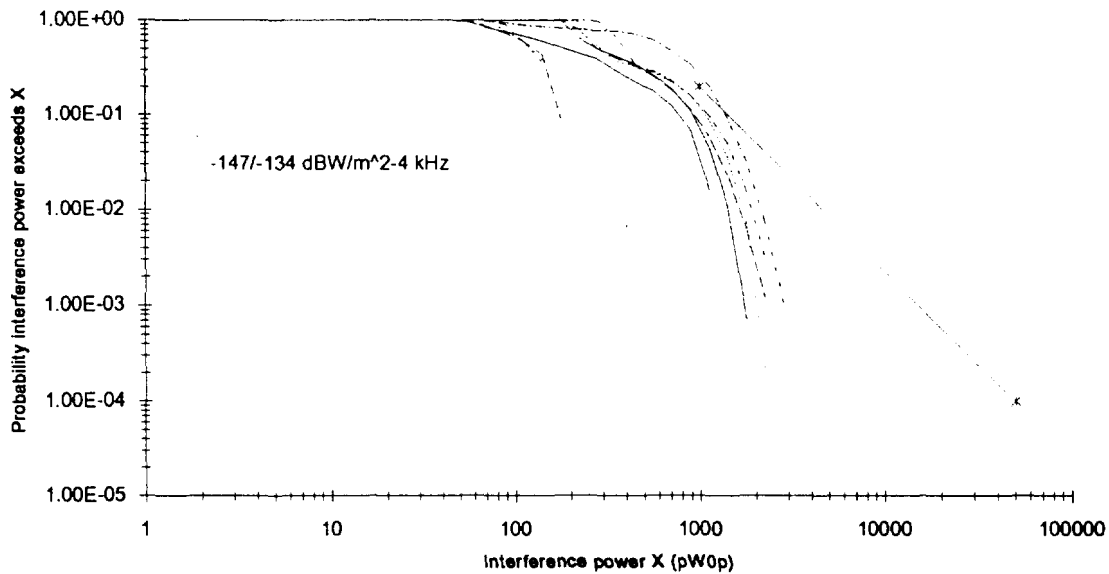
Figure 3 - Statistical interference to 2500 km analog line-of-sight radio-relay routes centered at 60 degrees latitude: G_0=33 dBi; 10 dB pfd escalation factor.

Figure 4 - Statistical interference to 2500 km analog line-of-sight radio-relay routes centered at 15 degrees latitude: G_0=33 dBi; 13 dB pfd escalation factor.

Figure 5 - Statistical interference to 2500 km analog line-of-sight radio-relay routes centered at 40 degrees latitude: G_0=33 dBi; 13 dB pfd escalation factor.

Figure 6 - Statistical interference to 2500 km analog line-of-sight radio-relay routes centered at 60 degrees latitude: G_0=33 dBi; 13 dB pfd escalation factor.

Annex 2

PFD Levels From Non-GSO MSS Systems To

Protect Digital Radio-Relay Systems

1. Introduction.

The purpose of this Annex is to present the results of an analysis to determine the pfd levels necessary to protect digital point-to-point and point-to-multipoint radio-relay systems from interference from the emissions of a LEO D type non-GSO mobile-satellite system. The methodology of Draft New Recommendation ITU-R [Doc. 9/178] was used for the analysis. The performance degradation of digital radio-relay systems is determined for stations located at 15 degrees, 40 degrees and 60 degrees latitude, and with azimuth angles that range from 0 degrees to 180 degrees in 2.5 degree steps.

The following sections describe the approach used for the study, the technical characteristics of the LEO D system, the technical characteristics of the digital radio-relay systems, a summary of the results of the analyses and the conclusions.

2. Analysis

2.1. Approach.

The methodology for the analysis is set forth in Draft New Recommendation ITU-R [Doc. 9/178]. It is assumed that the digital stations are centered at a given latitude. The azimuth angle of the station receiving antenna varies between 0 degrees and 180 degrees in 2.5 degree steps. Each station is assumed to use a high gain antenna at an elevation angle of 0 degrees.

The analysis is performed using a simulation program. The program assumes that the satellites move in circular orbits perturbed only by the oblateness of the earth. The program calculates the satellite orbital positions and visibility to each station in 8 second increments for one repeat cycle, which is 47.5 hours. At each time sample, the program calculates the aggregate interference noise power received at the station from all visible satellites as

$$I = \sum_{i=1}^{N} \rho(\delta_i) A_{iso} G(\theta_i)$$

where

  $i = 1$ of N visible satellites
  $\rho(\delta_i)$=the power flux-density received at the station from the ith satellite
  δ_i= the elevation angle from the station to the ith satellite
  A_{iso}= area of an isotropic antenna = $\lambda^2/4\pi$
  $G(\theta_i)$= station antenna gain in the direction of the ith satellite
  θ_i= angle between the station's antenna pointing vector and the range vector from the station to the ith satellite.

The program calculates the interference statistics based on the aggregate interference noise power calculated at each of the sample points. The interference statistics show the

probability that the aggregate received interference noise power equals a given interference level. It then calculates the fractional degradation in performance FDP for the digital station as

$$FDP = \sum_{I_i=\min}^{\max} \frac{I_i f_i}{N_T}$$

where

I_i = Interference noise power level.
f_i = the fractional period of time that the interference power equals Ii
N_T = station receiving system noise power level = kTB
k = Boltzmann's constant
T = station receiving system noise temperature
B = reference BW = 4 kHz

The fade margin loss FML is given by

FML = 10 log(1 + FDP)   dB

Figure 1 shows the fade margin loss plotted as a function of the fractional degradation of performance. As the figure shows, a 10% fractional degradation in performance equates to about a 0.4 dB loss in fade margin, while a 100% fractional degradation in performance corresponds to a 3 dB loss in fade margin.

The pfd incident on the station's receiving antenna as a function of the elevation angle was assumed to be of the form

$$\rho(\delta) = \rho(5) \qquad\qquad 0 \le \delta < 5 \deg \qquad (1a)$$
$$\rho(\delta) = \frac{\rho(25) - \rho(5)}{20}(\delta - 5) + \rho(5) \qquad 5 \deg \le \delta < 25 \deg \qquad (1b)$$
$$\rho(\delta) = \rho(25) \qquad\qquad 25 \deg \le \delta \le 90 \deg \qquad (1c)$$

where

δ= elevation angle (degrees)
ρ= pfd (dBW/(m²)) in a reference bandwidth
$\rho(5)$= pfd value at 5 degrees elevation and below
$\rho(25)$= pfd value at 25 degrees elevation and above

Two types of antennas are used for the digital systems: relatively high gain circularly symmetric type antennas; and, low to moderate gain antennas with constant gain in the azimuth plane and directional pattern in the elevation plane. All digital line-of-sight radio-relay systems and local-access systems using sector antennas are assumed to use antennas that are circularly symmetric. The radiation pattern of this type antenna is assumed to conform to the antenna pattern having averaged sidelobe levels as defined in Note 6 of Recommendation ITU-R F.699-1 as revised by the Study Group 9 Plenary meeting in March 1994. The reference radiation pattern is described in Section 2.1 of Annex 1 of this Recommendation.
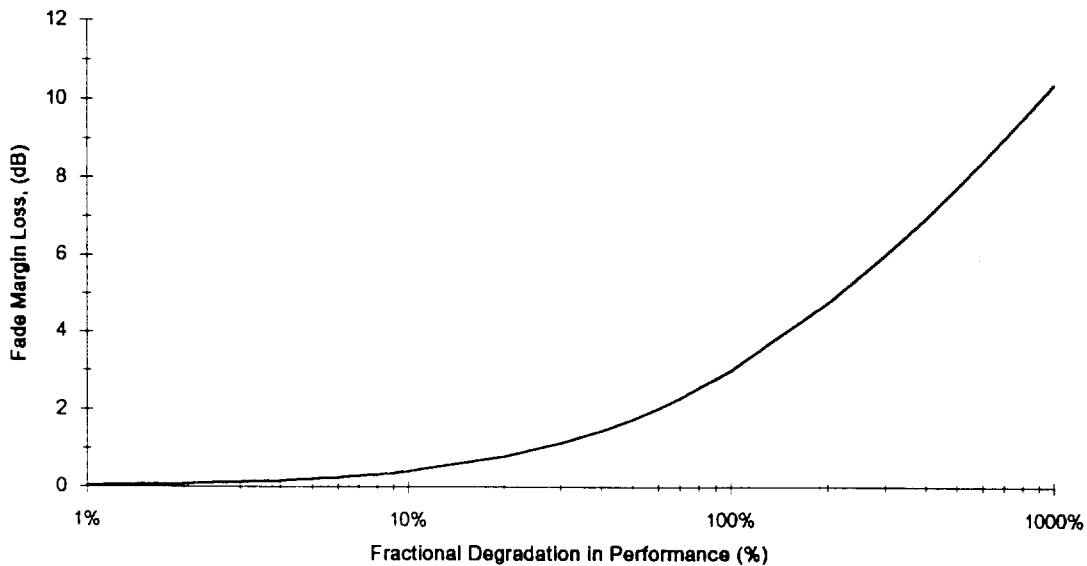
Figure 1 - Fade margin loss vs. fractional degradation in performance.

An omnidirectional antenna is used at the base station of some of the local access point-to-multipoint digital systems. A reference radiation pattern is required in order to characterize the interference to this type station. The pattern for the omnidirectional antenna was derived in the following way.

The derivation of the reference radiation pattern is based on the following assumptions combined with the material in [1]:

♦ that the antenna is an n-element linear array radiating in the broadside mode;
♦ the elements of the array are assumed to be isotropic radiators; and,
♦ the array elements are spaced $3\lambda/4$.

The 3 dB beamwidth ϕ_3 of the array in the elevation plane is related to the directivity D by [2]

$$D = 10\log\left[191.0\sqrt{0.818 + 1/\phi_3} - 172.4\right] \text{ dB} \qquad (2)$$

Equation (1) may be solved for ϕ_3 when the directivity is known

$$\phi_3 = \frac{1}{\alpha^2 - 0.818} \qquad (3a)$$

$$\alpha = \frac{10^{.1D} + 172.4}{191.0} \qquad (3b)$$

[1]   C.A. Balanis, Antenna Theory Analysis and Design, Harper & Row, Publishers, 1982, ch. 6, pp.204-282.
[2]   "Directivity of Omnidirectional Antennas," Antenna Designer's Notebook Section, IEEE Antennas and

The relationship between the 3 dB beamwidth in the elevation plane and the directivity was derived in [2] on the assumption that the radiation pattern in the elevation plane was adequately approximated by

$$f(\theta) = \cos^m(\theta)$$

where m is an arbitrary parameter used to relate the 3 dB beamwidth and the radiation pattern in the elevation plane. Using this approximation, the directivity was obtained by integrating the pattern over the elevation and azimuth planes.

The intensity of the far-field of a linear array is given by [1]

$$E_T(\theta) = E_e(\theta) \times AF(\theta) \tag{4}$$

where $E_T(\theta)$ is the total E field at an angle of θ to the normal to the axis of the array, $E_E(\theta)$ is the E field at an angle of θ to the normal to the axis of the array caused by a single array element, and $AF(\theta)$ is the array factor at an angle θ to the normal to the axis of the array. The array factor is

$$AF_n = \frac{1}{N}\left[\frac{\sin\left(\frac{N}{2}\psi\right)}{\sin\left(\frac{1}{2}\psi\right)}\right] \tag{5}$$

where N is the number of elements in the array, $\frac{\psi}{2} = \frac{1}{2}\left(2\pi\frac{d}{\lambda}\sin(\theta)\right)$, d is the spacing of the radiators and λ is the wavelength.

These equations have been evaluated and plotted on a spreadsheet. It has been found that the envelope of the radiation pattern in the elevation plane may be adequately approximated by the following equations

$$G(\theta) = G_0 - 12\left(\frac{\theta}{\phi_3}\right)^2, \quad dB \qquad\qquad 0 \leq \theta < \phi_3 \tag{6a}$$

$$G(\theta) = G_0 - 12 - 10\log\left(\frac{\theta}{\phi_3}\right), \quad dB \qquad\qquad \phi_3 \leq \theta \tag{6b}$$

The results are shown in Figures 2 through 5, respectively, for omnidirectional antennas exhibiting gains of 10 dBi, 11 dBi, 12 dBi and 13 dBi. As the figures show, the approximation is quite good for low to moderate elevation angles. The difference between the approximate envelope of the radiation pattern and the actual radiation pattern at high elevation angles will be better than shown in the figures because of the use of array elements with directivity.

2.2. Non-GSO LEO D satellite system parameters.

The following parameters were assumed for the non-GSO LEO D satellite system:

* 48 satellites that all transmit continuously.
* The 48 satellites are located in 8 orbital planes, which are separated by 45 degrees.
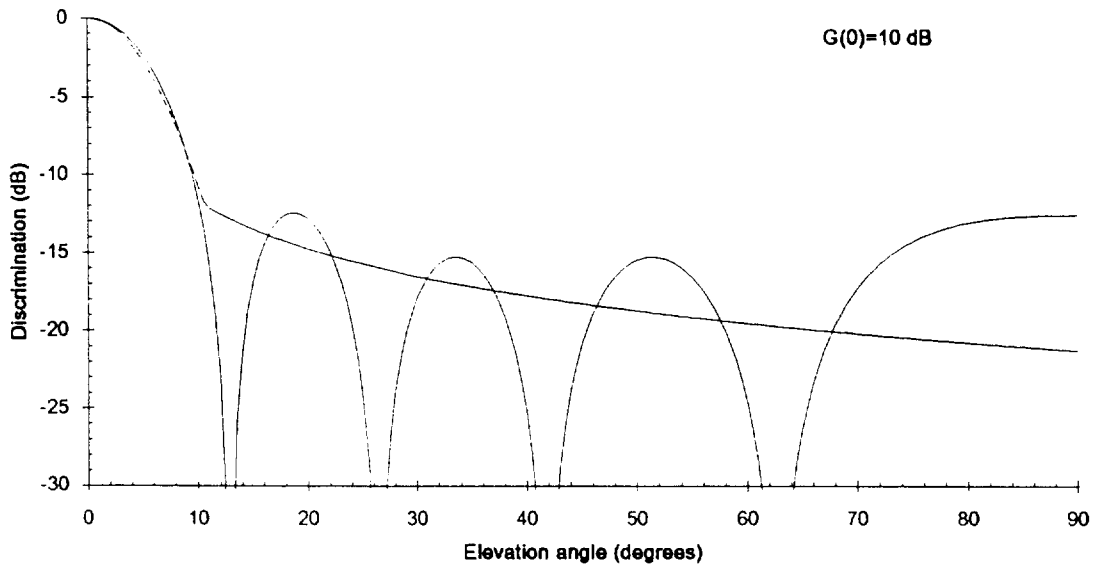* The difference between the mean anomaly of satellites in adjacent orbit planes is 7.5 degrees.

Figure 2 - Radiation pattern of a linear array compared with the approximate envelope of the radiation pattern: G(0)=10 dBi.

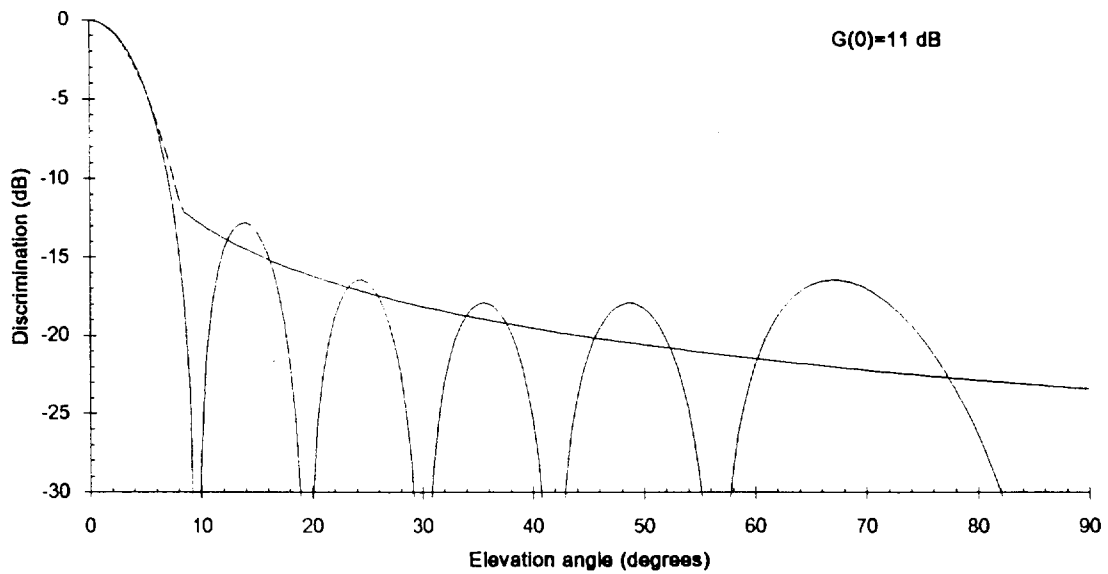- The six satellites in each plane are separated by 60 degrees.

Figure 3 - Radiation pattern of a linear array compared with the approximate envelope of the radiation pattern: G(0)=11 dBi.
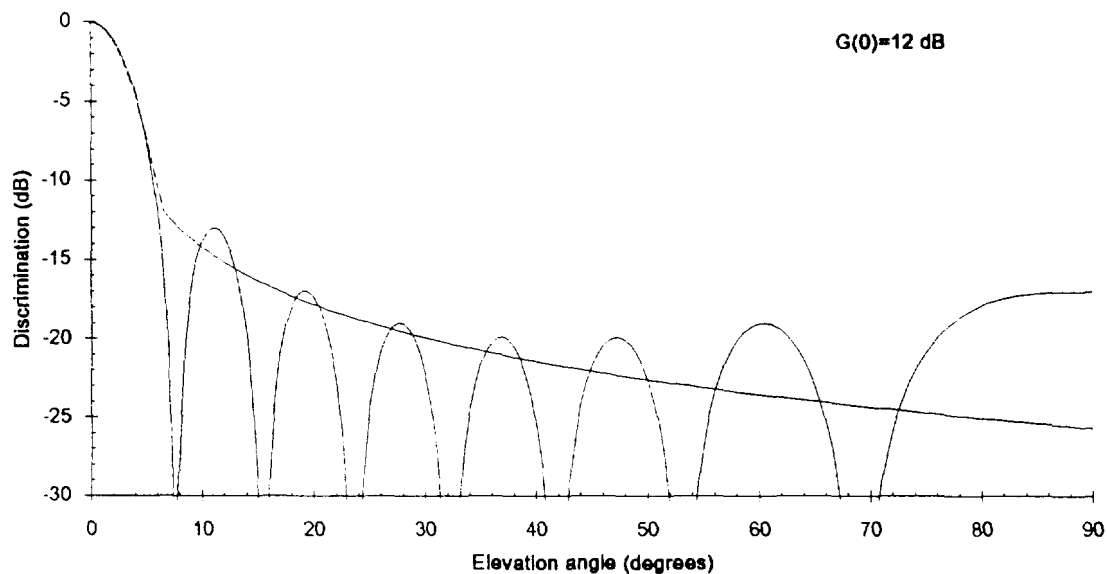
Figure 4 - Radiation pattern of a linear array compared with the approximate envelope of the radiation pattern: G(0)=12 dBi.
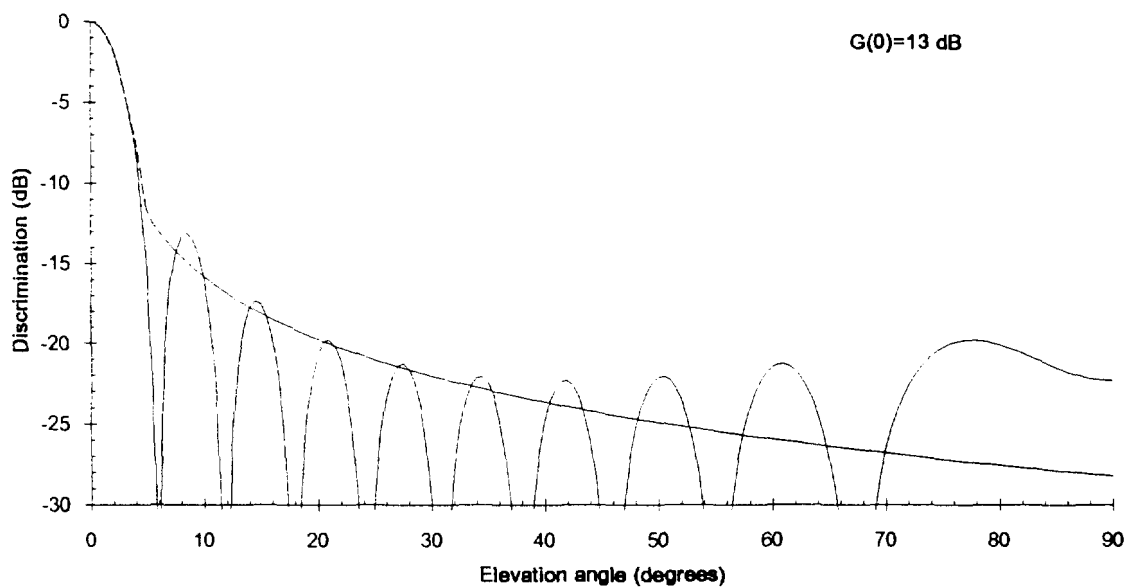

Figure 5 - Radiation pattern of a linear array compared with the approximate envelope of the radiation pattern: G(0)=13 dBi.

* The orbital altitude is 1414 kilometers (km).
* The orbit planes are inclined 52 degrees with respect to the equatorial plane.

2.3. PFD levels

As shown previously in equation (1), the pfd levels affecting the digital fixed service stations were assumed to be a minimum value for elevation angles less than 5 degrees, a maximum value for elevation angles greater than 25 degrees, and to linearly increase between the minimum and the maximum levels for elevation angles between 5 and 25 degrees. The pfd levels used in the analysis were

* Minimum value of -159 dBW/m^2 in a 4 kHz reference bandwidth escalating to a maximum value of -146 dBW/m^2 in a 4 kHz reference bandwidth; and,
* Minimum value of -159 dBW/m^2 in a 4 kHz reference bandwidth escalating to a maximum value of -149 dBW/m^2 in a 4 kHz reference bandwidth.

2.4. Digital fixed service station parameters.

The digital fixed service station parameters are:
* a single digital station located at 15 degrees, 40 degrees, or 60 degrees latitude.
* the azimuth angle of the receiving antenna varies between 0 degrees and 180 degrees in 2.5 degree steps.
* the antenna boresight gain for digital line-of-sight radio-relay stations are assumed to be 17 dBi, 20 dBi, 27 dBi and 33 dBi as suggested in Annex 1 to Doc. 2-2/TEMP/8(Rev.1).
* the gain for an omnidirectional antenna used for digital local access radio-relay systems is assumed to be 13 dBi as suggested in Annex 1 and Annex 3 to Doc. 2-2/TEMP/8(Rev.1).
* each digital station has a noise figure of 4 dB, a feed line loss of 2 dB and an antenna temperature of 290 K, also as suggested in Annex 1 and Annex 3 to Doc. 2-2/TEMP/8(Rev.1).

3. Results

3.1. Digital line-of-sight radio-relay stations.

The characteristics of the radio-relay stations are enumerated in Section 2.4, and the characteristics of the LEO D satellite orbits may be found in Section 2.2. Using these parameters, the fractional degradation in performanc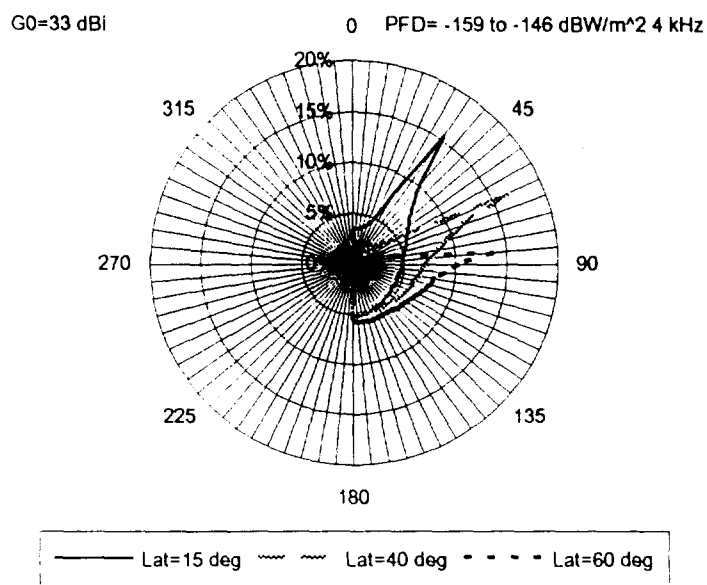e as a function of azimuth angle for digital line-of-sight radio-relay stations located at 15 degrees, 40 degrees and 60 degrees latitude is shown in polar plots in Figures 6 through 11. Figure 6 shows the FDP for stations using 33 dBi gain antennas for the case of pfd values ranging from -159 to -146 dB(W/m^2 4 kHz). As the figure shows, the maximum FDP ranges from about 9% for stations located at 60 degrees latitude to over 15% for stations located at 15 degrees latitude.

Similar to Figure 6, Figure 7 shows the FDP for stations using 33 dBi gain antennas for the case of pfd values ranging from -159 to -149 dB(W/m^2 4 kHz), a 10 dB escalation factor in the pfd. As the figure shows, the maximum FDP ranges from somewhat less than 9% for stations located at 60 degrees latitude to about 15% for stations located at 15 degrees latitude.

Figure 8 shows the FDP for stations using 27 dBi gain antennas and values of pfd ranging from -159 to -149 dB(W/m^2 4 kHz). For worst-case azimuth angles, the FDP exceeds 10%. For other azimuth angles, the FDP is greater than 5%. If the values of pfd are increased by 3 dB to -156 to -146 dB(W/m^2 4 kHz), the values of FDP will double.

Figure 9 shows the FDP for stations using 20 dBi gain antennas and values of pfd ranging from -159 to -149 dB(W/m^2 4 kHz). The effect of the broader receiving beamwidth on

the FDP is evident in the figure. For worst-case azimuth angles, the FDP exceeds between about 13% to 15%, depending on the latitude of the station. For other azimuth angles, the FDP is around 10%.

Figure 10 shows the FDP for stations using 17 dBi gain antennas and values of pfd ranging from -159 to -149 dB(W/m^2 4 kHz). The effect of the broader receiving beamwidth on the FDP is more pronounced in this figure than in Figure 9. For worst-case azimuth angles, the FDP exceeds between about 15% to 17%, depending on the latitude of the station. For other azimuth angles, the FDP is somewhat in excess of 10%.

3.2. Digital local access radio-relay stations.

The FDP for local access digital radio-relay stations employing omnidirectional antennas has been evaluated for values of pfd ranging from -159 to -149 dB(W/m^2 4 kHz). The omnidirectional antenna was assumed to have a maximum gain of 13 dBi in the horizontal plane. The gain in the elevation plane was assumed to be approximated by a reference radiation pattern as discussed in Section 2.1. The results are given in Table 1. It is seen that the FDP is about 10% for the latitudes considered.

Table 1 - FDP as a function of latitude for local access digital radio-relay stations using omnidirectional antennas: G_0=13 dBi; pfd=-159 to -149 dB(W/m^2 4 kHz).

Latitude (degrees)	FDP
15	10.43%
40	9.39%
60	8.89%

4. Conclusions.

From the results presented here, it may be concluded that pfd levels on the order of -159 to -149 dB(W/m^2 4 kHz) are needed to ensure that the FDP for digital line-of-sight radio-relay systems and for digital local access radio-relay systems does not significantly exceed 10% for a considerable range of azimuth angles.
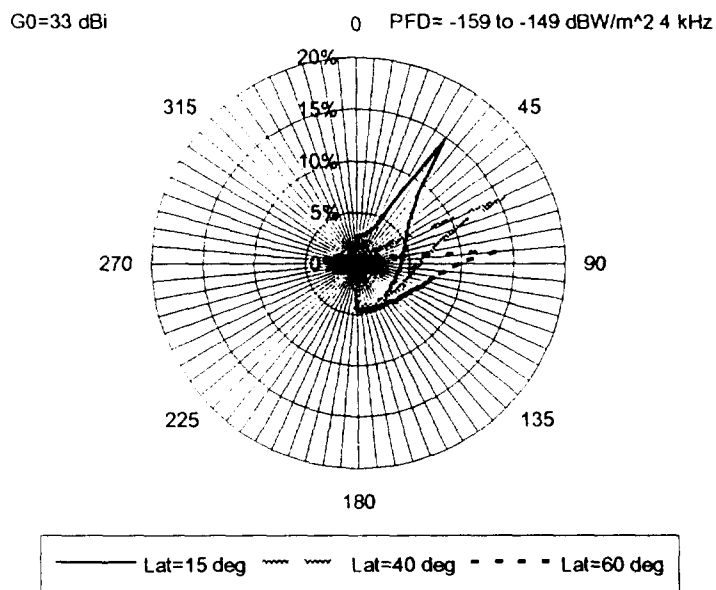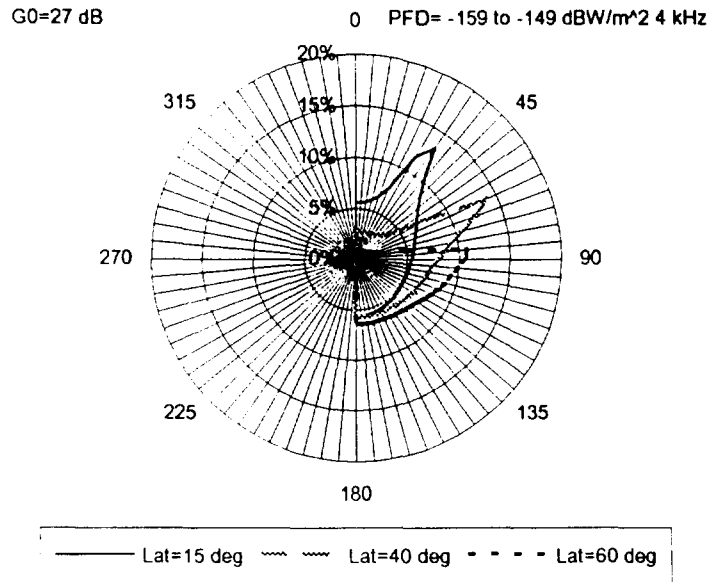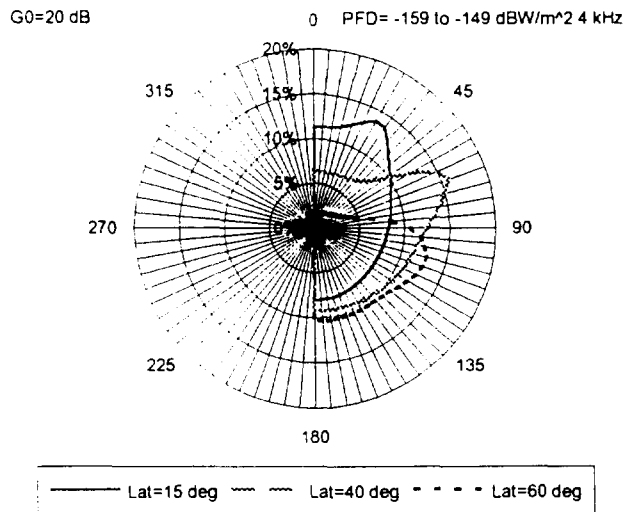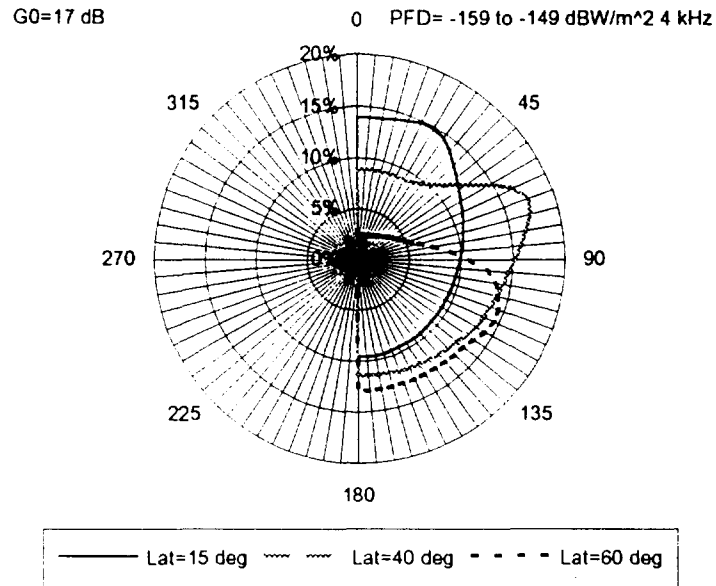
GO=33 dBi   0   PFD= -159 to -146 dBW/m^2 4 kHz

Figure 6 - FDP as a function of azimuth angle for digital line-of-sight radio-relay stations located at 15 degrees, 40 degrees and 60 degrees latitude: G_0=33 dBi; pfd= -159 to -146 dB(W/m² 4 kHz).

GO=33 dBi   0   PFD= -159 to -149 dBW/m^2 4 kHz

Figure 7 - FDP as a function of azimuth angle for digital line-of-sight radio-relay stations located at 15 degrees, 40 degrees and 60 degrees latitude: G_0=33 dBi; pfd= -159 to -149 dB(W/m² 4 kHz).

G0=27 dB   0   PFD= -159 to -149 dBW/m^2 4 kHz

Figure 8 - FDP as a function of azimuth angle for digital line-of-sight radio-relay stations located at 15 degrees, 40 degrees and 60 degrees latitude: G_0=27 dBi; pfd= -159 to -149 dB(W/m^2 4 kHz).

G0=20 dB   0   PFD= -159 to -149 dBW/m^2 4 kHz

Figure 9 - FDP as a function of azimuth angle for digital line-of-sight radio-relay stations located at 15 degrees, 40 degrees and 60 degrees latitude: G_0=20 dBi; pfd= -159 to -149 dB(W/m^2 4 kHz).

G0=17 dB   0   PFD= -159 to -149 dBW/m^2 4 kHz

Figure 10 - FDP as a function of azimuth angle for digital line-of-sight radio-relay stations located at 15 degrees, 40 degrees and 60 degrees latitude: G_0=17 dBi; pfd= -159 to -149 dB(W/m^2 4 kHz).

ATTACHMENT 3

COMSEARCH

Study of 5000 - 5250 MHz Band for
a Globalstar Feeder Uplink

Prepared for
Loral Qualcomm Satellite Services, Inc.

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